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REVIEW

Risk and Protective Factors for Sudden Cardiac Death During Leisure Activities in the Mountains: An Update

Martin Burtscher, MD, PhD [a,b*]

[a]Department of Sport Science, Medical Section, University of Innsbruck, Innsbruck, Austria
[b]Austrian Society for Alpine- and High-Altitude Medicine, Innsbruck, Austria

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Introduction Annually, more than 100 million tourists with widely varying health and fitness status are attracted by the mountainous areas around the world. Whereas mountaineering activities may contribute to the well established beneficial effects of regular exercise, for certain individuals these activities are also associated with a relatively high risk of death.

Methods This manuscript presents an updated overview of risk and protective factors for sudden cardiac death during leisure activities in the mountains.

Results Sudden cardiac death (SCD) has been proven to be the most frequent cause of non traumatic death in males aged over 34 years, e.g. during mountain hiking, cross country skiing or downhill skiing. Risk factors for cardiovascular diseases and, in particular, prior myocardial infarction, are the most important risk factors for SCD, predominantly relevant in downhill skiers. The unusual physical exertion on the first day at altitude, the late morning hours and the prolonged abstinence from food and fluid intake during exercise at altitude are most important triggers. Acute hypoxia may represent a trigger for SCD on the one hand but might also evoke beneficial effects by preconditioning on the other hand.

Conclusion The identification of high-risk subjects and SCD triggers, evidence-based therapy of treatable risk factors, the appropriate individual preparation by physical training, and considering behavioural aspects, especially at the beginning of the physically active altitude sojourn will help to prevent SCD and increase the health benefits generated by mountaineering activities.

Keywords Mountaineering • Sudden cardiac death • Altitude • Exercise • Prevention

Introduction

The number of tourists enjoying leisure activities in the higher elevations of mountainous areas is still increasing all over the world. About 35 million mountain tourists annually have been estimated for the Western United States [1], 40 million for the Alps and more than 100 million worldwide [2]. For example, the number of arrivals in Nepal increased from 6,179 in 1962 to 162,897 in 1980 to 463,646 in 2000 and to 803,092 in 2012 [3]. Recent reports on skiing activities refer to more than 2,000 downhill ski areas and a total number of about 400 million skier days each year [4]. Mountaineering activities like mountain hiking, trekking, rock and ice climbing, ski mountaineering, mountain biking, downhill skiing, and cross country skiing are usually characterised by strenuous exercise often in a hypoxic and cold environment. On the one hand regular physical activity and probably also exposure to moderate altitudes up to about 2,500 m may contribute to well-being and longevity [5–7]. On the other hand, however, unaccustomed exercise especially in extreme

*Corresponding author at: Fürstenweg 185, University of Innsbruck, 6020 Innsbruck, Austria. Email: martin.burtscher@uibk.ac.at

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environmental conditions, i.e. altitude and cold, may trigger serious cardiovascular adverse events, i.e. sudden cardiac deaths (SCDs), in subjects at risk [8–12]. Sudden cardiac death is defined as unexpected, non traumatic death within one hour after the onset of symptoms [2]. The identification of individuals at risk, reliable knowledge on risk factors, triggers and underlying pathophysiological mechanisms are of utmost importance to establish effective measures for prevention. Therefore, this manuscript intends to present an updated overview of risk and protective factors for SCD and the measures to minimise the risk.

The Risk of Fatal Cardiovascular Events

Epidemiological studies demonstrate that mortality during mountain sports activities vary markedly depending on the type of activity, the population at risk, the type of terrain and altitude [13]. For example, Shlim and Gallie reported 40 deaths out of 275,950 trekkers in Nepal (up to ~ 5,000m) where four deaths (10%) resulted from heart attacks [10,14]. A recent study found skiing, cycling, and snow shovelling to be the most common modes of exercise at the time of SCD [15]. However, it is important to emphasise that those SCDs did not occur at altitude. Westensee et al. reported that out of 33 fatalities on Aconcagua (Andes mountain range, South America, 6,962m) five (15.2%) were due to hypothermia and four (12.1%) were SCDs [16]. Among Iranian high-altitude mountaineers five (17%) out of 29 deaths were SCDs [17]. Based on long-term observations in the Austrian Alps (up to ~ 3,800m) an annual death rate per 100,000 persons increasing from 0.76 in downhill skiers to 3.97 in mountain hikers to 6.77 in rock- and ice- climbers was recorded [10,18]. Importantly, about 25% of all deaths were attributed to SCDs. The frequencies of SCDs were particularly high in mountain sports particularly preferred by older subjects, e.g. mountain hiking, cross country and downhill skiing. For example, about 58% of mountain hikers and 43% of downhill skiers have been shown to be aged over 40 years and 15.3 to 28.0% of those suffered from pre-existing cardiovascular diseases [19]. Probably as a result, the SCD risk when hiking and cross country skiing or downhill skiing in the mountains increases sharply with age. Noteworthy, males were about 15 times more affected than females but with regard to the exposure times the SCD risk was about 20-fold higher for males. Consequently, male hikers and skiers over the age of 34 comprise about 90% of all SCDs [10,20]. When considering exposure times, one SCD per 400,000 hours has been calculated for male cross-country skiers, one SCD per 800,000 hours for male mountain hikers, and one SCD per 1,500,000 hours for male downhill skiers with an age over 34 years [10,21]. However, with regard to the duration of downhill skiing (excluding the resting times during transportation by ski lifts and cable cars) the SCD risk would be similar to that during mountain hiking [21]. In comparison to the SCD risk in males of the overall population aged between 35 and 70 years (1 SCD per 3,370,000 hours) [10,22] the SCD risk is about eight times higher for cross country skiers, and about four times higher for mountain hikers and downhill skiers. Noteworthy, about 50% of all SCDs occurred on the first day when performing mountaineering activities at altitude [10,20] indicating an about 8- to 30-fold increase in the SCD risk on this day compared to the overall male population aged over 34 years. Heavy physical exertion per se (also at low altitude) has been shown to increase the SCD risk up to about 17-fold compared to no exertion, especially in subjects not used to vigorous exercise [23]. The much lower risk for female mountaineers is in line with the findings from a large prospective cohort of women reporting an about 19-fold lower SCD risk during physical exertion for women compared to men [24]. Thus, the SCD risk during mountaineering activities, at least on the first day at altitude, seems not to be largely different from that during unusual heavy exercise at low altitude, in both men and women.

Triggers of Fatal Cardiovascular Events

As already mentioned, our long-term observations from Alpine regions indicate that the risk of suffering from SCD during hiking and skiing is greatest on the first day at altitude when 50% of all SCDs occur. These emergencies are most frequently observed in the late morning hours and increase with the duration from the last food and fluid intake [10,20]. Therefore, the unusual physical exertion on the first day at altitude, late morning hours and likely dehydration and depletion of carbohydrate stores may all release similar internal triggers of cardiovascular events [10]. These triggers provoke an increase in sympathetic activity likely precipitating arrhythmias and SCD [23,25]. More pronounced adrenergic activity is accompanied by abrupt changes in heart rate and blood pressure with subsequent haemodynamic stress, increased oxygen demand, disruption of vulnerable atherosclerotic plaques, and platelet activation resulting in increased thrombogenicity [26–29]. Although the studies discussed above do not directly support a role for environmental conditions one cannot exclude that additional stressors like altitude per se, extreme cold or hot environmental temperatures might also contribute to the risk of cardiovascular events in the mountains [11,12,30–32]. Woods et al. demonstrated not only the feasibility of using implantable loop recorders (ILR) for the evaluation of arrhythmias at high altitude but also the occurrence of significant arrhythmias even in healthy males during exercise at altitude [30]. Recently, a higher SCD risk has been demonstrated when sleeping at low altitudes during the first night before performing mountaineering activities at moderate to high altitudes [33]. Consequently, sleeping closer to the altitude where activities are performed may induce some acclimatisation or hypoxia preconditioning associated with a lower SCD risk. Some evidence of beneficial effects due to hypoxia

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